

Impact of Fall-Seeded Cover Crops and Cover Crop Termination Method on Weed Biomass in the Ensuing Crop.

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SUMMARY

The inclusion of cover crops in a rotation can have several potential benefits, one of which is weed suppression in the following crop. Rye, and to a lesser extent wheat and hairy vetch, tissues are known to contain compounds which may inhibit the germination of small-seeded weeds when released into the soil during residue decomposition. Method of cover crop termination alters factors such as residue/soil contact and therefore may affect the extent of weed suppression. This study investigated the effect of five cover crop treatments (winter rye, winter wheat, hairy vetch, winter rye/hairy vetch intercrop and winter wheat/hairy vetch intercrop), in concert with three termination methods (disk, roller/crimper and wide sweep) on weed pressure in the subsequent cash crop. Overall, greater grass weed biomass occurred in crops following hairy vetch and winter rye than crops following winter wheat or the winter rye/hairy vetch intercrop. The effect of cover crop on broadleaf weed biomass in the subsequent crop was more complex, varying with termination method.

INTRODUCTION

Incorporating cover crops into a rotation is an excellent strategy for building organic matter and enhancing soil health, while also providing fertility and weed and disease suppression. The positive effects of cover cropping have been long recognized, but have grown in favor only recently as input costs rise. Cover crops are typically either relay-intercropped with a cash crop, or grown over a full season to provide a break in pest cycles. In either case, the crop provides an actively growing soil cover which suppresses weeds while still promoting soil microbiological activity, and serves as a source of organic matter and essential nutrients upon termination. Weed suppression occurs through direct competition while the cover is actively growing, as well as through the exudation of allelopathic compounds by some crops.

Allelopathic compounds are chemicals synthesized by growing plants that can suppress the germination of seeds of potential competitors. This

suppression can occur not only while the crop is growing, as the chemicals are exuded from the roots of the plant, but can also persist after termination as these compounds leach from the crop residue. It is generally accepted that the allelopathic potential is greatest if the crop residue remains on the soil surface (Putnam et al., 1983). Generally, allelopathic chemicals are most effective in suppressing germination as seed size decreases. Many problematic weeds in agricultural systems produce large quantities of small, easily dispersed seeds, so enhancing the allelopathic effect of cover crop residues could provide weed suppression in the following crop, at least for a period of time long enough to endow the crop with a competitive advantage. Furthermore, most field crops will remain unaffected by allelopathy due to the somewhat larger seed size.

One crop most commonly cited for its allelopathic potential is rye, which is often used by organic growers as a weed suppressant and catch crop. Research suggests that allelopathic compounds synthesized by a rye cover crop may not only provide weed control while the crop is growing, but can remain effective germination-inhibitors of small-seeded weeds for some time after termination of the crop (Teasdale et al., 1991). However, incorporation of residues leads to more rapid decomposition and dissolution of these allelopathic compounds, as compared with leaving the residue on the soil surface, which allows the chemicals to leach more slowly from the residues (Putnam et al., 1983).

To harness the potential benefits of allelopathy, a roller/crimper has been used to terminate rye without disturbing the soil surface. The roller/crimper consists of a cylindrical drum with parallel chevron-shaped ridges which crush but do not cut the stalk of the growing crop, ideally resulting in firmly packed mulch on the soil surface into which the subsequent crop can be no-till seeded. This method can be used with other cover crops as well, and has achieved some success in several areas in the United States and abroad. However, it generally is necessary for rye (and many

other crops) to have reached at least the onset of flowering before rolling can effectively kill the plant.

Mowing, or other tillage methods can be used for cover crop termination as well. However, the burying of potentially allelopathic residue that results from tillage is known to reduce its effectiveness as a weed control device, while the exposure and disturbance of the soil surface resulting from tillage may also create favorable conditions for weed seed germination. Soil disturbance also destroys soil structure, reduces moisture retention and enhances the breakdown of organic matter; therefore, minimal soil disturbance is often recommended as a strategy for improving soil quality. Unfortunately, tillage is heavily relied upon in organic and some low-input management systems to control weeds. The potential of cover crops to enhance soil quality and ameliorate the detrimental aspects of tillage is great, while termination of these crops without soil disturbance, and their potential for weed suppression could reduce dependence on tillage in the above-mentioned management systems.

Cover cropping is also a useful way to enhance soil fertility. In order to maximize the supply of nutrients added to the soil, leguminous cover crops are often incorporated into rotations, due to their ability to fix significant amounts of nitrogen. In fact, including a broad selection of crops in the rotation, as well as applying organic amendments, is an important strategy for increasing the organic matter content of the soil. The inclusion of combinations of low and high-quality crop residues is important because high quality, low C:N ratio materials decompose quickly, contributing very little to overall OM content. Lower quality residues, on the other hand, break down more slowly in the soil due to higher C:N ratios. These low-quality residues increase soil organic matter content but contribute very few potentially mineralizable compounds (Seiter and Horwath, 2004). Therefore a diversity of crop residues ensures sufficient organic C and N for humus formation and ultimately engenders a pool of potentially available nutrients that can become mobilized according to crop demand. The importance of organic matter additions, through the inclusion of cover crops in the rotation as well as manure or compost application, cannot be overestimated. In fact, research has shown that when 150 lb/ac of synthetic nitrogen fertilizer is applied to a corn crop, soil organic matter still supplies up to 70% of the N taken up by the corn (Omay et al., 1998). Furthermore, it is

estimated that 20 to 70% of the soil cation exchange capacity is due to humic substances, which highlights the importance of organic matter for nutrient storage (Seiter and Horwath, 2004).

The potential of cover crops for weed control, combined with their ability to enhance fertility and soil quality while sustaining ecosystem services during periods of non-cash cropping, suggest many benefits if incorporated into cropping systems. A potential fit for cover crops in the northern plains is seeding these crops post harvest and terminating in the spring prior to seeding a cash crop. The objective of the current study was to screen three different species for use as cover crops, including winter rye (WR), winter wheat (WW) and hairy vetch (HV) sown individually, as well as winter rye/hairy vetch (WR+HV) and winter wheat/hairy vetch (WW+HV) intercrops. Crops were evaluated specifically for their ability to reduce weed densities in a variety of subsequent cash crops (buckwheat, sweet corn and navy bean) without interfering with crop performance. A coincident goal of the study was to determine which method of termination - disking, wide sweep/noble blade, or roller/crimper - was most effective at killing the cover crop and also resulted in the least amount of weed pressure in the subsequent crop.

MATERIALS AND METHODS

Cover crop treatments consisted of winter rye (WR, 'Dakold'), winter wheat (WW, 'Ransom') and hairy vetch (HV, Common) sown individually as well as winter rye/hairy vetch (WR+HV) and winter wheat/hairy vetch (WW+HV) intercrops. All crops were seeded on September 20, 2007. The previous crop was oat and no fertilizer was applied prior to seeding the cover crops. The WR treatment was seeded at a rate of 140 lb/ac and the WW treatment was seeded at a rate of 150 lb/ac. In the WR+HV treatment rye was seeded at a rate of 112 lb/ac and vetch was seeded at a rate of 25 lb/ac, while in the WW+HV treatment wheat was seeded at 120 lb/ac and vetch at 25 lb/ac. Experimental design was a **strip-split block** and consisted of four randomized complete blocks with each block containing the three termination methods (disk, wide sweep, roller/crimper) established in random order. The cover crop treatments were established randomly in within each tillage treatment, even though tillage treatments were not applied until after the cover crop treatments

were in place. Cover crop treatments were seeded in strips 10 ft wide and 42 ft long. All crops were seeded with a John Deere 750 low-disturbance drill into a no-till seed bed. Termination of cover crops was accomplished with the implements mentioned above being run through the cover crop treatments parallel to seeding direction.

Cover crop plant counts were taken from a 0.5/m² area in the six cover crop treatments within one of the tillage treatments in each block on October 11, 2007. Counts were taken again in the spring to evaluate crop winter survival. First flowers were observed in rye and vetch on June 16, 2008 and in wheat one week later. Approximately one week was then allowed for the stands to reach full flower, at which time the covers were terminated. The WR, WR+HV and HV treatments were terminated on June 24, 2008 and the WW and WW+HV treatments were terminated on July 2, 2008. Cover crop biomass, along with grass and broadleaf weed biomass samples were taken from a 0.5/m² area within the first six cover crop treatment plots in each block just prior to termination. Broadleaf, grass and cover crop samples were separated and weighed. Samples were then dried at 130° F for 3 to 4 days and reweighed to obtain dry weight and moisture content.

On July 3, 2008, cash crops were seeded in random order within each of the four blocks in 6 ft wide, 180 ft long strips perpendicular to tillage and cover crop strips with a cross-slot no-till drill. Cash crops initially consisted of buckwheat ('Koma'), carrot ('Nelson'), sweet corn ('Earlivee'), navy bean ('Vista'), pinto bean ('Maverick'), and spring wheat ('Parshall'), although the carrot, pinto bean and wheat treatments were abandoned due to extremely poor germination and crop performance. An unplanted check treatment was also included along with the cash crop strips to determine weed pressure in absence of crop competition. Seeding rates were as follows: buckwheat at a rate of 52 lb/ac, carrot at 9 lb/ac, sweet corn at 7.5 lb/ac, navy bean at 40 lb/ac, pinto bean at 50 lb/ac and wheat at 65 lb/ac.

Cash crop plant counts were performed on July 25 for buckwheat and navy bean and July 28 for sweet corn to determine stand biomass. Cash crops were harvested, along with grass and broadleaf weeds, on September 15 and 16. Crop, grass weed and broadleaf weed sampled were separated and dried at 130° F for 3 to 4 days before being weighed.

Statistical analysis was performed to determine the effect of cover crop and termination method on weed biomass in the subsequent crop and yield of subsequent crop. Analysis was conducted using SAS version 9.1 (SAS Institute, 2003), and consisted of a mixed model approach with block being a random factor and tillage, cover crop and main crop being fixed factors and the cover crop being nested within the tillage factor ($\alpha = 0.05$). Interaction effects were evaluated by pairwise comparisons of least squares means with mixed model ANOVA.

RESULTS

Cover Crop Survival and Biomass

Winter rye survival was 92% in the WR treatment and 90% in the WR+HV treatment. Hairy vetch survival was 74% when grown alone, 40% in mixture with winter rye and 37% in mixture with winter wheat. Winter wheat survival was 42% alone and 36% in mixture with hairy vetch.

The WW, WR and WR+HV cover crop treatments produced the most biomass, while the HV treatment produced the least (Fig. 1). The fact that the WW treatment produced the most overall biomass is interesting given the poor winter survival of winter wheat. It is likely that, due to dry spring conditions, the lower plant population of winter wheat reduced intraspecific competition and in turn enhanced performance, compensating for low density. The fact that the intercropping of hairy vetch with winter wheat seems to have reduced the overall amount of biomass produced supports this hypothesis. In terms of winter rye, on the other hand, overall biomass in the rye/vetch intercrop was virtually indistinguishable from the rye sole crop. Generally, the weed suppressant potential of cover crops increases with increasing cover crop biomass. More biomass results in a thicker mulch layer, which serves to physically inhibit weed seed germination, and increases the potential of allelopathic crops. In both cases the weed suppressant effect is most pronounced when the residue is left on the soil surface, rather than incorporated. Obviously, cover crops producing more biomass will also be more competitive with weeds while actively growing. Therefore, the performance of winter wheat, winter rye and the winter rye/hairy vetch intercrop indicate potential for cover cropping in this region based on the amount of biomass produced, as well as their potential

allelopathic effect. Still, actual weed suppressant ability is the most important factor in this context.

Effect of Cover Crop on Grass Weed Biomass in Subsequent Crop

An overall effect of cover crop on grass weed biomass in the subsequent crop was observed, with more weeds by weight being present in crops following HV and WR covers than in crops following the WR+HV intercrop (Fig. 2). Termination method and main crop had no effect on grass weed biomass. Increased grass weed biomass under hairy vetch as compared with the hairy vetch/winter rye could be explained by vetch's lack of allelopathic effect, as well as the fact that the rapid decomposition of vetch (due to its low C:N ratio) could supply readily available nutrients for weed proliferation. The greater grass weed biomass after the winter rye sole crop compared to the winter rye/hairy vetch intercrop, on the other hand, is somewhat curious. If anything, it would seem logical that the winter rye sole crop would have an increased allelopathic effect in relation to the intercrop with hairy vetch. However, the interaction between the two crops and effects on soil ecology, microbial community structure and nutrient and moisture availability are likely to have had an influence on the reduced amount of grass weeds observed following the rye/vetch intercrop.

Effect of Cover Crop on Broadleaf Weed Biomass in Subsequent Crop

An effect of cover crop and termination treatments on broadleaf weed biomass in the subsequent cash crop was observed, while main crop, whether buckwheat, corn or navy bean, had no effect on broadleaf weed biomass. Weed biomass was greater following the HV treatment when terminated by the roller/crimper compared with weed biomass following HV in the two other tillage treatments (Fig. 3). This effect was also observed in the WW+HV treatment, while broadleaf weed biomass following the WW treatment was greater when terminated by the roller only in comparison with the wide sweep termination method. Broadleaf weed biomass in the WR+HV treatment was greater when the cover was disked than when it was rolled. To clarify, hairy vetch and the winter wheat/hairy vetch intercrop suppressed weeds in the subsequent crop to a greater extent when terminated with the disk or wide sweep than with the

roller/crimper, while winter wheat suppressed weeds to a greater extent when terminated with the wide sweep than when terminated with the roller. The winter rye/hairy vetch intercrop, on the other hand, suppressed weeds in the subsequent crop to a greater extent when terminated with the roller/crimper than when terminated with the disk. Broadleaf weed suppression by winter rye was not affected by termination method.

Weed suppression was linked not only to the cover crop, but to the method by which the cover was terminated. In the case of the HV treatment, broadleaf weed control was reduced in the subsequent crop when the vetch was terminated by the roller. This may be a corollary of the rapid breakdown of the vetch residue and the minimal mulch that was therefore available to smother weed seedlings. In this case, performing tillage provided conditions less conducive to weed germination or survival, a fact that could be attributed to the exposure and subsequent desiccation of weed seeds resulting from tillage, especially given the extremely dry conditions. Furthermore, within the roller termination treatment, broadleaf weed biomass was greater following vetch than any other cover crop.

Given that it has been documented that rye, wheat and hairy vetch produce allelopathic compounds (Barnes et al., 1987, Putnam et al., 1983 and White et al., 1989), the fact that less broadleaf weed biomass was recovered from roller terminated treatments including rye or wheat could suggest a greater allelopathic effect from these crops. However, it is likely that this could again be due to the fact that the greater abundance of residues resulting from the other crops physically suppressed weed seed germination to a greater extent. In fact, in a similar study, Teasdale et al. (1991) found very little difference in the ability of rye and hairy vetch residues to suppress weeds in a subsequent corn crop, and identified the amount of biomass as the major factor in the extent of weed suppression.

Interestingly, within the four cover crop treatments that included a cereal, there was not a consistent reduction of subsequent weed biomass when terminated with the roller as compared to the other termination methods. For instance, while in the WR+HV treatment reduced broadleaf weed biomass was found subsequent to rolling as opposed to disking, the method of termination of the WR cover crop had no effect on subsequent weed biomass. Furthermore,

in the WW cover crop more weed biomass was subsequently recovered in the roller treatment than in the wide sweep treatment and in the WW+HV cover crop weed biomass was greater following the rolling than following either of the other two termination methods. Any effect of allelopathy as affected by tillage is therefore difficult to ascertain from these results, and in fact the positive effects of reduced till such as greater moisture retention may actually be a factor in the increased weed biomass present after rolling as opposed to the other termination methods.

Effect of Cover Crop on Subsequent Crop Biomass

Due to extremely dry conditions and the late date of planting there was no harvestable crop following any of the cover crop treatments. However, crop biomass was collected at the same time as weed biomass. No direct effect of cover crop on main crop biomass was observed, although there was a termination method effect on overall main crop biomass. Regardless of cover crop, all crops tended to yield better after the wide sweep termination treatment, even though biomass was very low in all cases (Table 1). This could be attributed to the effect of slight disturbance on soil biology. The minimal soil disturbance occurring with the wide sweep could have stimulated mineralization by aerating soil and bringing plant debris into closer contact with the soil. At the same time, this implement still left the majority of the plant residue on the soil surface, which could have led to increased moisture retention compared with disk tillage.

The need to defer rolling until flowering to prevent cover crop regrowth delayed planting of the main crop to an extent that severely hampered development. Lack of rainfall was a prominent factor in reducing crop performance, while diminishing day length and a limited growing season also played a role. In a year with normal precipitation it is possible that cover crop flowering would be significantly earlier and therefore allow for earlier seeding of the cash crop. This would obviate concerns related to day and season length but given that dry conditions are common in the latter part of the growing season in this region the availability of moisture for the cash crop would still be of concern. The benefit of heavy residue

on the soil surface that results from no-till termination of the cover crop would be negligible if the cover had exhausted available soil moisture. Termination methods involving tillage could potentially be used to kill cover crops earlier in the season than could be done with the roller/crimper, allowing for early seeding of the cash crop, and possibly better utilization of spring rains. High-residue implements would be required to maximize soil cover, but this method (as with any tillage event) would be at least somewhat detrimental to soil structure and reduce water infiltration and storage, especially over time.

CONCLUSION

These results indicate that there was no cover crop or cover crop mixture that clearly suppressed all weeds to a greater extent than any other in the subsequent crop. Relative to hairy vetch alone covers including winter rye and winter wheat showed some potential in suppressing grass weeds, as well as broadleaf weeds in the subsequent crop when terminated by the roller. Whether this was an allelopathic effect, an effect on soil biology or nutrient availability, or simply a physical effect of no-till negating conditions necessary for weed seed germination is unclear. There was also no termination method that was clearly preferable. Conclusions as to the effect of cover crop on subsequent cash crop are difficult to make given the extremely dry conditions and the late date of planting. However, cash crops tended to fair best following the wide sweep termination method, for reasons discussed above.

This study also suggests that a cropping system in which covers are fall-seeded and spring-terminated may not be the best option for the northern plains, given precipitation and season length limitations. However, this study has only occurred in one year, and an extremely dry year at that, so strong conclusions cannot be drawn. If cover crops could in fact be terminated earlier the system could have potential in this region, and ultimately further research is necessary to identify whether this system of cover cropping or another is the best strategy for enhancing weed control while maintaining soil fertility and minimizing moisture loss.

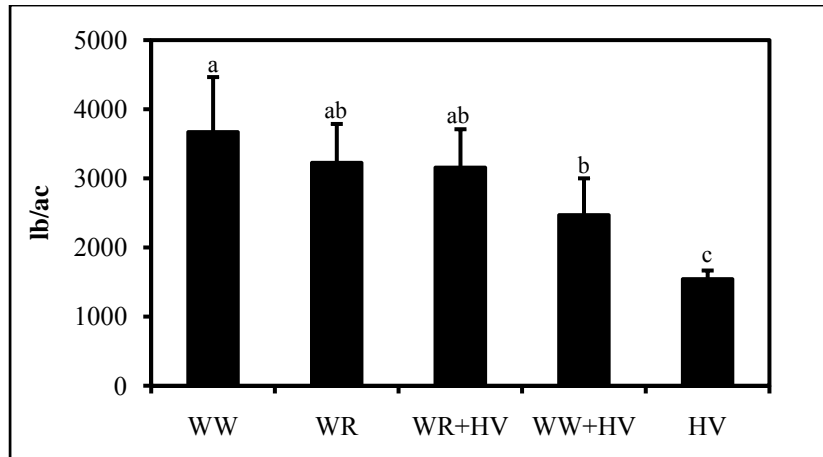


Figure 1. Overall biomass generated by cover crops.

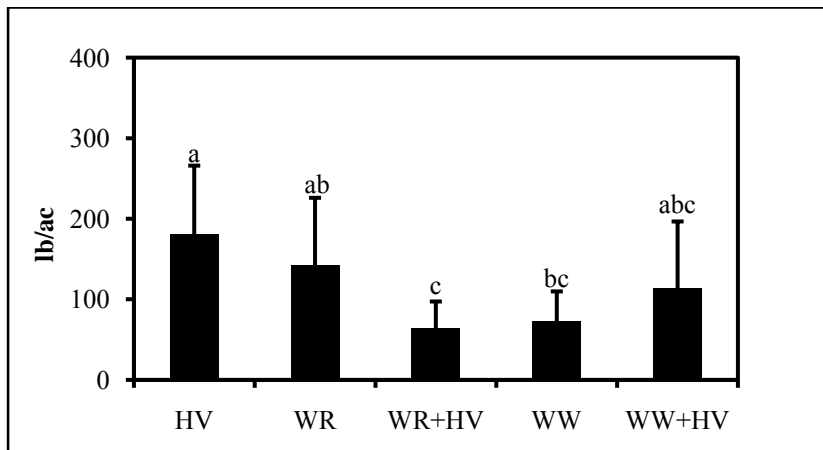


Figure 2. Grass weed biomass in subsequent crop as influenced by cover crop. Quantities with the same letter do not differ.

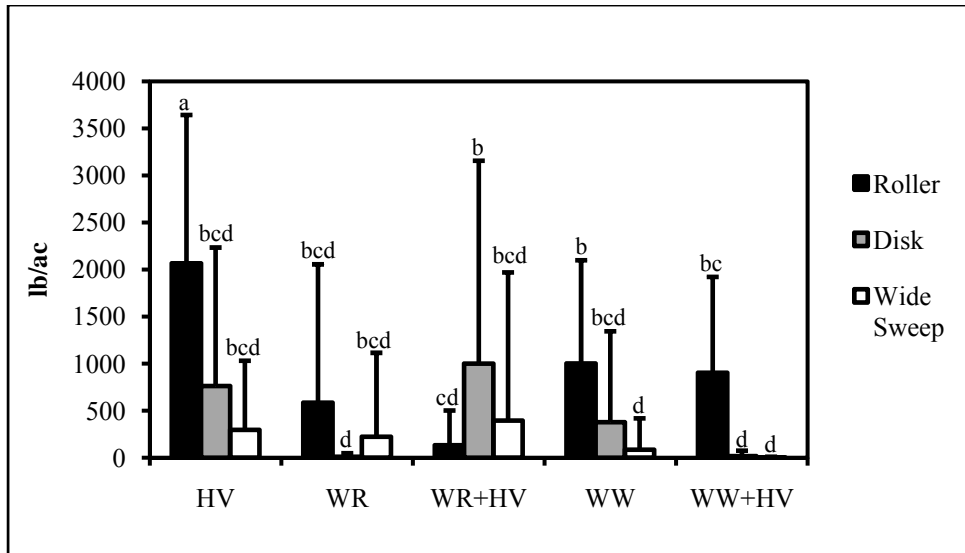


Figure 3. Broadleaf biomass in subsequent crop as influenced by cover crop and termination method. Quantities with the same letter do not differ.

Table 1. Overall main crop biomass (buckwheat, corn and navy bean) as affected by cover crop and termination method. Quantities with the same letter do not differ.

Termination Method	Cover Crop	Overall Main Crop Biomass — lb/ac —
Wide Sweep	HV	535.61a
Wide Sweep	WR	413.56ab
Disk	WR+HV	379.06b
Wide Sweep	WW	373.08b
Wide Sweep	WR+HV	319.49bc
Wide Sweep	WW+HV	278.42bcd
Disk	WR	272.62bcd
Disk	WW	265.75bcde
Disk	HV	212.78cdef
Disk	WW+HV	202.29cdef
Roller	WR+HV	130.97defg
Roller	WW+HV	117.20efg
Roller	WR	96.43fg
Roller	WW	45.26g
Roller	HV	6.51g

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